CHAPTER 2

APPLICATION

A. Traffic Control Zones

When traffic is affected by construction, maintenance, utility, or similar operations, traffic control is needed to safely guide and protect motorists, pedestrians, and workers in a traffic control zone. The traffic control zone is the distance between the first advance warning sign and the point beyond the work area where traffic is no longer affected.

Most traffic control zones can be divided into the following parts:

- Advance Warning Area,
- Transition Area,
- Buffer Space,
- Work Area, and
- Termination Area.

If no lane or shoulder closure is involved, the transition area will not be used. In this chapter, each of the "Parts" will be examined for one direction of travel. If the work activity affects more than one direction of travel, the same principles apply to traffic in all directions.

Figure 1 illustrates the five parts of a traffic control zone to be discussed in this section. The devices used in these areas, for different types and locations of work, are compared in Table 1.

1. Advance Warning Area

An advance warning area is necessary for all traffic control zones because drivers need to know what to expect. Before reaching the work area, drivers should have enough time to alter their driving patterns. The advance warning area may vary from a series of signs starting a mile in advance of the work area to a single sign or flashing lights on a vehicle.

Advance warning signs may not be needed when the work area, including access to the work area, is entirely off the shoulder and the work does not interfere with traffic. An advance warning sign should be used when any problems or conflicts with the flow of traffic might possibly occur.

AREAS IN A TRAFFIC CONTROL ZONE

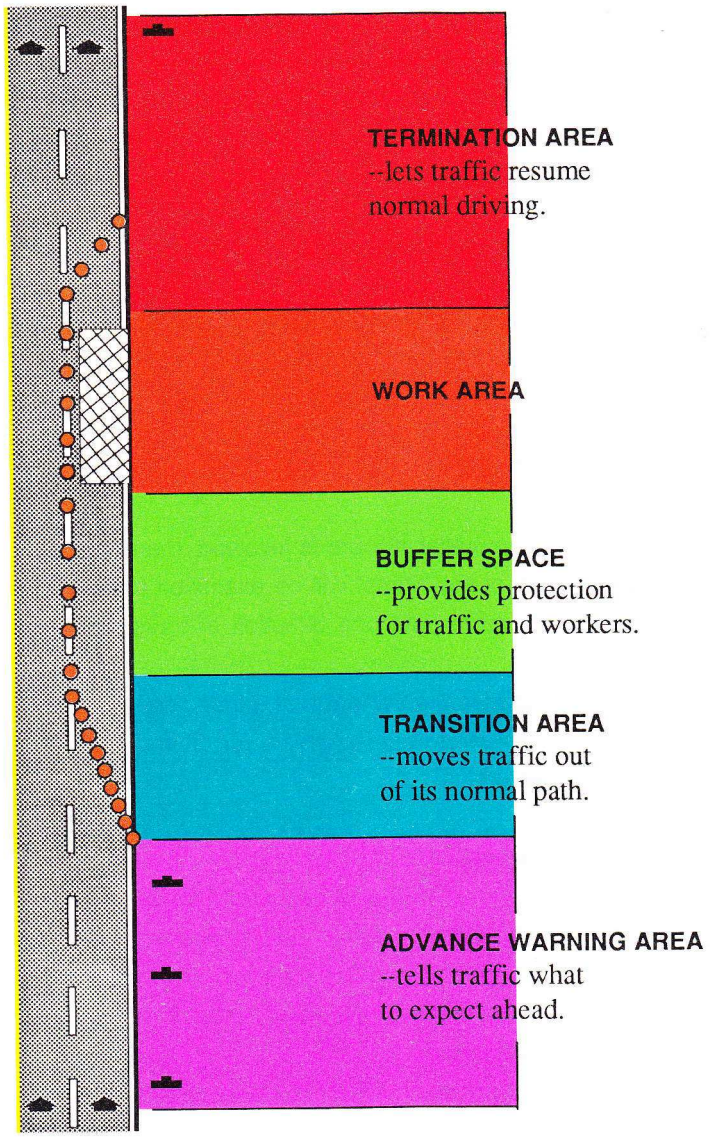
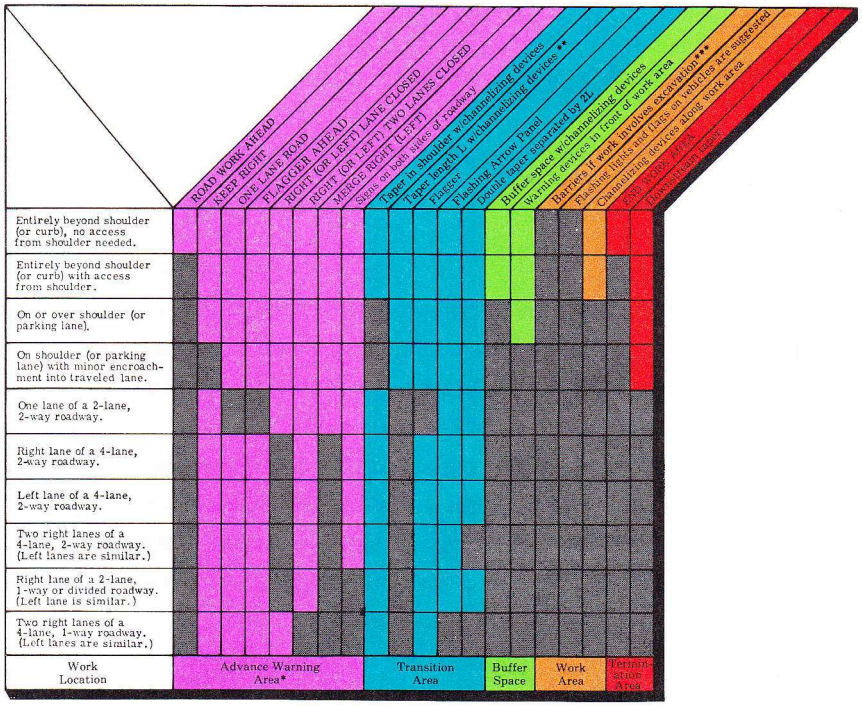


Figure 1

TRAFFIC CONTROL DEVICES FOR VARIOUS LOCATIONS OF WORK



* A consistent pattern of messages is shown in this figure. Refer to MUTCD for other acceptable messages or symbol signs.

** Old pavement markings should be removed and new markings placed in transition area for longer-term activities.

***The use of barriers is determined by an engineering analysis of the need for positive protection.

TABLE 1

Length of the Advance Warning Area

The advance warning area, from the first sign to the start of the next area, should be long enough to give the motorists adequate time to respond to the conditions. For most operations, the length can be:

- One-half mile to one mile for freeways or expressways;
- 1,500 feet for most other roadways or open highway conditions; and
- At least one block for urban streets.

For some specific applications refer to Figures 8 through 23, pages 60-79, "Typical Applications (Layouts)".

2. Transition Area

When work is performed within one or more traveled lanes, a lane closure(s) is required. In the transition area, traffic is channelized from the normal highway lanes to the path required to move traffic around the work area. The transition area contains the tapers which are used to close lanes.

The transition area should be obvious to drivers. The correct path should be clearly marked with channelizing devices and pavement markings so drivers will not make a mistake and follow the old path. Existing pavement markings need to be removed when they conflict with the transition. New markings should be added. Pavement marking arrows are useful in transition areas.

With moving operations, the transition area moves with the work area. A shadow vehicle may be used to warn and guide traffic into the proper lane. Refer to "Shadow Vehicles", page 51.

Tapers

A taper is a series of channelizing devices and pavement markings placed on an angle to move traffic out of its normal path. An example of a taper is shown in Figure 1, page 12.

Four general types of tapers used in traffic control zones are:

- Lane closure tapers are those necessary for closing lanes of moving traffic (sometimes referred to as channelizing tapers).

- Two-way traffic tapers are those needed to control two-way traffic where traffic is required to alternately use a single lane (commonly used when flaggers are present).

- Shoulder closure tapers are those needed to close shoulder areas.

- Downstream tapers are those installed to direct traffic back into its normal path.

Lane Closure Taper

The single most important element, within the system of traffic control devices commonly used in construction or maintenance areas (where a reduction in pavement width is involved), is the taper that is provided for the channelization. An inadequate taper will almost always produce undesirable traffic operations with resulting congestion and possibly accidents through the area.

The length of taper used to close a lane is determined by the speed of traffic and the width of the lane to be closed (the lateral distance that traffic is shifted). There are two formulas for determining the length of a taper (L) used for lane closures.

The minimum desirable taper length for construction and maintenance purposes should be computed by the formula $L = S \times W$, for all freeways, expressways, and other roadways having a posted speed of 45 mph or greater. The formula $L = WS^2/60$ should be used to compute taper length on urban, residential and other streets where the posted speeds are 40 mph or less. Under either formula, L equals the taper length in feet, W the width of offset in feet, and S the posted speed or off-peak 85 percentile speed.

The formulas and their criteria for application are shown in Table 2.

FORMULAS FOR TAPER LENGTH

Posted Speed	Formula
40 mph or under	$L=\frac{WS^2}{60}$
45 mph or over	L=WS

where: L = taper length

W = width of lane or offset

S = posted speed, or off-peak 85 percentile speed

TABLE 2

If restricted sight distance is a problem (e.g., a sharp vertical or horizontal curve), the taper should begin well in advance of the view obstruction. The beginning of tapers should not be hidden behind curves. Table 3 shows the taper length, the recommended number, and the spacing of channelizing devices for various speeds and widths of closing.

TAPER LENGTHS FOR LANE CLOSURES-DISTANCE L

Speed Limit M.P.H.	Taper Length Lane Width In Feet 10	11	12	Number of Channelizing Devices for Taper*	Spacing of Devices Along Taper in Feet
20	70	75	80	5	20
25	105	115	125	6	25
30	150	165	180	7	30
35	205	225	245	8	35
40	270	295	320	9	40
45	450	495	540	13	45
50	500	550	600	13	50
55	550	605	660	13	55

TABLE 3

*Based on 12-foot wide lane. This column is appropriate for lane widths less than 12 feet.

Generally, tapers should be lengthened, not shortened, to increase their effectiveness. Traffic should be observed to see if the taper is working correctly. Frequent use of brakes and evidence of skid marks is an indication that either the taper is too short or the advance warning is inadequate. Section D, "Typical Applications (Layouts)", page 57, includes several typical applications which illustrate how tapers may be placed in urban areas in the vicinity of intersections.

Two-Way Traffic Taper

The two-way traffic taper is used in advance of a work area that occupies part of a two-way road in such a way that the remainder of the road is used alternately by traffic in either direction. In this situation, the function of a taper is not to cause traffic to merge, but rather to resolve the potential head-on conflict. A short taper is used to cause traffic to slow down by giving the appearance of restricted alignment. Drivers then have time at reduced speed to decide whether to proceed cautiously past the work space or to wait for opposing traffic to clear. One or more flaggers are usually employed to assign the right-of-way in such situations.

Two-way traffic tapers should be 50 to 100 feet long, with channelizing devices spaced a maximum of 10 to 20 feet respectively, to provide clear delineation of the taper. Flashing arrows boards (in the arrow mode) should never be used with a two-way traffic taper.

Shoulder Closure Taper

When an improved shoulder is closed on a high-speed roadway, it should be treated as a closure of a portion of the roadway because motorists expect to be able to use the shoulder in the event of an emergency. The work area on the shoulder should be preceded by a taper that may be shorter than for lane closures. One-half of the length from Table 3 (page 16) is suggested as a maximum for shoulder closure tapers, provided the shoulder is not used as a travel lane. If the shoulder is being used as a travel lane, either through practice of through use caused by construction, a standard lane closure taper should be placed on the shoulder.

Downstream Taper

A downstream taper is used at the downstream end of the work area to indicate to drivers that they can move back into the lane that was closed. It is placed in the termination area. While closing tapers are optional, they may be useful in smoothing

traffic flow. They may not be advisable when material trucks move into the work area by backing up from the downstream end of the work area.

Closing tapers are similar in length and spacing to two-way traffic tapers.

3. Buffer Space

The buffer space is open or unoccupied space between the transition and work areas (Figure 1, page 12). With a moving operation, the buffer space is the space between the shadow vehicle, if one is used, and the work vehicle.

The buffer space provides a margin of safety for both traffic and workers. If a driver does not see the advance warning or fails to negotiate the transition, a buffer space provides room to stop before the work area. It is important for the buffer space to be free of equipment, workers, materials, and workers' vehicles. When designing or setting out a Traffic Control Plan the following guidelines should be considered for buffer spaces:

- Place channelizing devices along the edge of the buffer space. The suggested spacing in feet is equal to two times the posted speed limit.

- Situations occur where opposing streams of traffic are transitioned so one lane of traffic uses a lane that normally flows in the opposite direction. In these situations, a buffer space should be used to separate the two tapers for opposing directions of traffic because it could help prevent head-on collisions. Refer to Figure 16, page 70, for an example of this type of buffer space.

4. Work Area

The work area is that portion of the roadway which contains the work activity and is closed to traffic and set aside for exclusive use by workers, equipment, and construction materials. Work areas may remain in fixed locations or may move as work progresses. An empty buffer space may be included at the upstream end. The work area is usually delineated by channelizing devices or shielded by barriers to exclude traffic and pedestrians and serve as protection for the workers.

Conflicts and Potential Hazards

Conflicts between traffic and the work activity are potential hazards. These increase as:

- The work area is closer to the traveled lanes;
- Physical deterrents to normal operation exist such as uneven pavements, vehicles loading or unloading;
- Speed and volume of traffic increase; and
- The change in travel path gets more complex, shifting traffic a few feet in comparison with shifting traffic across the median and into lanes normally used by opposing traffic.

Work areas that remain overnight have a greater need for delineation than daytime operations.

Every feasible effort should be made to minimize conflicts. Some suggestions include:

- Use traffic control devices to make the travel path clearly visible to traffic.
- Place channelizing devices between the work area and the traveled way. Devices placed on a tangent (along the work area) to keep traffic out of a closed lane should be spaced in accordance with the extent and type of activity, the speed limit of the roadway, and the vertical and horizontal alignment such that is is apparent that the lane is closed. The MUTCD does not specify a spacing for the devices along the closed lane. For high-speed roadways, a range from 2S to 4S (two to four times the posted speed limit) is suggested. For low-speed or urban streets, a closer spacing may be used.
- Provide a safe entrance and exit for work vehicles.
- Protect mobile and moving operations with adequate warning on the work and/or shadow vehicles.
- Flags and flashing lights should be considered on work vehicles exposed to traffic.

5. Termination Area

The termination area provides a short distance for traffic to clear the work area and to return to the normal traffic lanes. It extends from the downstream end of the work area to the END CONSTRUCTION or END ROAD WORK sign. A downstream taper may be placed in the termination area.

For some work operations, such as single location utility or maintenance repair, it may not be necessary to display a sign as it will be obvious to drivers that they have passed the work area.

There are occasions where the termination area could include a transition. For example, if a taper were used to shift traffic into opposing lanes around the work area, then the termination area should have a taper to shift traffic back to its normal path. This taper would then be in the transition area for the opposing direction of traffic. It is advisable to use a buffer space between the tapers for opposing traffic, as shown in Figure 16 (page 70).

Avoid "gaps" in the traffic control that may falsely indicate to drivers that they have passed the work area. For example, if the work area includes intermittent activity throughout a 1-mile section, the drivers should be reminded periodically that they are still in the work area. The primary purpose of the guide sign ROAD CONSTRUCTION NEXT ___ MILES is to inform the drivers of the length of the work area. It should not be erected until work begins.

B. Planning for Traffic Control

During planning for work zones, one should strive for the greatest payoff in terms of safety and convenience at a cost commensurate with the hazards and problems involved. A properly installed traffic control zone will allow traffic to pass through or around a work zone safely. It requires time and effort for planning, installation, and maintenance. All employees involved with work-zone safety should be properly trained. These include design, traffic and construction engineers, inspectors, superintendents, and foremen.

All work-zone traffic-control planning centers around an analysis of the work activity and relating it to the provision of adequate safety and capacity. What is the likelihood of motorists failing to negotiate the work zone safely? What are the consequences of such action on pedestrians, workers, or other motorists?

Planning for traffic control through a construction zone may be more involved than for maintenance or utility zones because of the differences in traffic disruption and duration of the work. Although the requirement for safety in all zones is the same, planning for the three types of work operations will be discussed separately. The exposure of traffic to potential hazards is a function of the traffic volume and the length of time that the closure will be in effect. The goals common to all traffic control zones are:

- to minimize accidents and accident severity; and
- to minimize inconvenience and conflict as a result of the work. It should be recognized that these goals may at times be at odds.

1. Minimize Accidents

For all work zones, the first fundamental principle is that safety should have a high priority through all stages of all work. The following list is a set of guidelines that may be helpful in achieving this goal:

- Use traffic control devices that are visible and effective.
- Follow the standards in the MUTCD on the use and location of tapers and transitions. Avoid introducing severely reduced travel path geometrics at the approaches to or within the work area.
- Minimize fixed object hazards. For example, use lightweight channelizing devices and use crash cushions to protect barrier ends. Sand bags should be placed on the bottom of supports for various devices so that they do not become projectiles as a result of a collision.
- Minimize traffic conflicts with workers and equipment. Consider using a portable barrier.
- Provide night visibility with illumination, reflectorized devices, warning lights, and pavement markings. Consider floodlighting hazardous areas. However, care should be taken to insure that the floodlights are not aimed in a way that would adversely affect motorist's vision.

- Close only those lanes that must be closed and reopen them as soon as practicable to maintain maximum roadway capacity.

- Avoid severe speed reductions.

- Avoid traffic delays that could cause backups.

- Avoid scheduling work during peak hours and holidays.

- Prepare an alternate route or plan in case of an accident or other emergency. If an alternate route is not feasible, be prepared to use signs, flaggers, and radio announcements to warn traffic of the backup and to explain the delay.

- Reduce inconveniences for pedestrians and bicyclists by providing the shortest and safest path, safe clearances, and minimum grades, steps, and curbs.

- Emergency organizations, such as police, fire, and ambulance services, should be notified prior to the start of work. This will allow them to adjust their routes and/or work schedules accordingly.

- Emergency vehicles should have a high priority in passing through a work zone or using an alternate route.

- Access to police and fire stations, fire hydrants, and hospitals should be maintained at all times.

3. Utility Work Zones

Utility work may be divided into three classifications: emergency, maintenance and new construction. The guidelines for traffic control listed here are for normal situations and additional protection should be provided when special complexities and hazards exist.

Emergency Work

- Can occur at any time of day or night;

- May be caused by storm damage;

- Provide safe pedestrian walkways by separating pedestrians from vehicular traffic and work activities. Provide safe pedestrian and vehicular access across or through driveways.

- Store equipment and materials outside the clear recovery zone as defined in the Guide for Selecting, Locating, and Designing Traffic Barriers (List of References #3).

- Provide a buffer space between traffic and workers.

- Provide safe employee access to work, storage areas, businesses, residences, and within the work area. Provide a safe entrance and exit for work vehicles. This may require the use of temporary traffic signals, flaggers, or temporary portable barriers.

- Plan for the safety of workers on the project as required by safety and health regulations. (e.g., safety clothing, hardhats, etc.)

- Flags and flashing lights should be utilized on work vehicles exposed to traffic. To protect mobile and moving operations, shadow vehicles may be used and equipped with signs, flags, flashing lights, and/or crash cushions as appropriate.

2. Minimize Inconvenience

Work in or near traveled lanes often causes confusion and disruption of normal traffic. The traffic control plan should be aimed at reducing inconvenience and conflicts, as stated above. Traffic movement should be inhibited as little as practicable. Traffic control in work sites should be designed on the assumption that motorists will only reduce their speeds if they clearly perceive a need to do so. Reduced speed zoning should be avoided as much as practicable. Frequent and abrupt changes in geometrics, such as lane narrowing, dropped lanes, or main roadway transitions which require rapid maneuvers, should be avoided. Provisions should be made for the safe operation of work vehicles, particularly on high speed, high volume roadways. Construction time should be minimized to reduce exposure to potential hazards.

The following list is a set of guidelines that may be helpful in achieving this goal:

- May involve disruptions of utility service to customers;

- Work operation usually involves a small crew and a work vehicle for a short period of time;

- The work vehicle should be equipped with a yellow flashing light, a limited number of portable signs and channelizing devices in good condition, and equipment for flaggers in the event they are needed; and

- The extent of traffic control may be less than longer-term construction or maintenance, yet the safety of pedestrians, motorists, and workers should be provided.

4. Maintenance and New Construction for Utilities

The public will not easily make a distinction between maintenance and new construction. Therefore the type of traffic control used should be adequate for the nature, location, and duration of work, type of roadway, traffic volume and speed, and potential hazard. When new construction or some maintenance activities are planned (as opposed to emergency activities), the following guidelines should be considered:

- In urban areas, consider avoiding the hours of peak traffic when scheduling work.

- Maintain street and road work areas for only as long as is necessary to safely move in, finish the work, remove all utility work signs, and move out.

- Take special care to clearly mark suitable boundaries for the work space with channelizing devices so pedestrians and drivers can see the work space. If any of the traveled lanes are closed, tapers shall be used as required by the MUTCD. If a shoulder is closed, a shoulder taper is suggested.

- Pedestrians should not be expected to walk on a path which is inferior to the previous path. Loose dirt, mud, broken concrete, or steep slopes may force

pedestrians to walk on the roadway rather than the sidewalk. Repairs (temporary or permanent) to damaged sidewalks should be made quickly. This may include bridging with steel plates or good quality wood supports.

- Any work which cannot be completed during the day and which impedes traffic or presents a hazard overnight may need additional attention. Reflectorized signs and channelizing devices are required by the MUTCD. Warning lights are optional but should be considered.

- Any member of the crew who serves as a flagger should be equipped with a red flag or a STOP-SLOW paddle, a reflective vest, and should be trained for proper flagging procedures.

- Work areas involving excavations on the roadway generally should not exceed the width of one traffic lane at a time. The work should be staged and, if needed, approved bridging should be utilized. This type of activity should be fully coordinated with the Traffic Engineering Division or Public Works Department office having jurisdiction over the street or highway.

5. Highway Maintenance Work Zones

Maintenance operations are needed to preserve, repair, and restore the streets and highways and include those activities performed on travel-way surfaces, shoulders, roadsides, drainage facilities, bridges, signs, markings, and signals.

These operations may be emergencies (as a result of storms or accidents) or planned activities. They may be stationary, mobile, or moving operations. The traffic control needed will vary according to the nature, location, and duration of work; type of roadway; speed of traffic and potential hazard.

6. Traffic Control Plans for Construction Projects

A formal Traffic Control Plan (TCP) is required to be included in the plans, specifications and estimates (PS&E) for all Federal-aid projects by Federal-Aid Highway Program Manual (List of References #4.) Other construction projects should also have a TCP. These plans may range in scope from a very detailed TCP designed solely for a specific project, to a reference to standard plans, a section of

the MUTCD, or a standard highway agency manual such as this Handbook. The degree of detail in the TCP will depend on the complexity of the project and on the interaction of traffic needs and construction activities.

Highway agency design and traffic engineers will develop the TCP and include it in the PS&E. The contractor can develop a TCP, but may use it only if it is equal to or better than the TCP in the plans, and if it is approved by the highway agency.

The following people and organizations are normally involved in the development of a TCP:

- Transportation officials from local, state, and federal levels, including design, traffic, and construction engineers;
- Police and fire officials at the state and local levels; and
- Utility companies.

Once the TCP has been developed and approved but before construction starts, others should be notified, as follows:

- Businesses in the area;
- Affected public groups, such as homeowners' organizations;
- School officials, so they can change bus schedules if necessary;
- Local government officials, including the Chamber of Commerce; and
- Tow truck services.

The following factors need to be considered for the TCP:

- Economic and community
  - commercial business districts,
  - residential locations,
  - recreation areas,
  - shopping centers,

- railroad crossings,
- rural areas, and
- other work planned adjacent to or within the area of the project;

- Traffic
  - volumes,
  - peak hours including holiday, special event and recreation traffic,
  - pedestrian traffic,
  - bicycles,
  - large vehicles such as trucks and buses,
  - speed of traffic,
  - capacity of roadway,
  - traffic signal operation (effect on existing vehicle detectors); and

- Seasonal changes and weather, including
  - maintaining traffic control during seasonal shutdowns,
  - loss of visibility and damage to devices during rain or snow,
  - temperature restrictions for some phases of construction, and
  - maintenance of traffic control devices (cleaning, cutting vegetation away from signs).

A 24-hour workday may be desirable as it allows the total number of working days to be decreased. Consideration should include:

- Neighborhood objection to nighttime noise;

- Higher cost, for labor and lighting;

- Higher percentage of drinking drivers at night; and

- Limited available commercial services, such as supply of ready-mix concrete or aggregate.

The controlled staging of construction should be considered, including:

- The location of work (on roadway, shoulders, or sidewalks);
- The number of lanes required for the work activity;
- Hours of a day during which a lane may be closed;
- Whether work may progress simultaneously in both directions of traffic;
- The length of the work area (controlled staging such as guardrail removal and immediate replacement);
- Minimize time of exposure to hazards such as drop-offs;
- Time involved, such as curing of pavement or bridge decks;
- Remove or shield the motorist from hazards created by the work activity within the recovery area such as boulders, drainage basins, pipe, headwalls, blunt ends of guardrail, and sign supports; and
- Delays during traffic control set-up and take-down time (preferably during low traffic volume periods).

Traffic control planning should consider the inclusion of unit pay items in the construction contract to cover the furnishing, application, installation, and maintenance of traffic control devices of acceptable quality to comply with the agency's specifications.

Materials developed for the TCP may include but are not limited to:

- Scaled drawings of the control zone;
- List of devices selected for installation;
- Special manpower needs, such as flaggers;

- Copies of permits;
- Phone numbers of officials to be contacted in an emergency;
- Scaled drawings of construction stages, including detours; and
- Schedules for times during the day when work is permitted or when certain lanes should remain open.

7. Speed Control for Detours, Transitions, & Median Crossovers

Studies have shown that reliance upon speed zone signing alone is not an effective method of reducing travel speeds in work zones. This should be recognized during the design of the project. The following are some guidelines for determining speed limits in detours, transitions, and median crossovers:

- Detours and crossovers should be designed for speeds equal to the existing speed limit if at all possible. Speed reductions should not be more than 10 mph below the limit of the entering roadway.
- Where a speed reduction greater than 10 mph is unavoidable, the transition to the lower limit should be made in steps of not more than 10 mph.
- Where severe speed reductions are necessary, police or flaggers may be used in addition to advance signing. The conditions requiring the reduced speed should be alleviated as soon as possible.

8. Transitional Areas from Construction Zones to Sections of Older Roadways

Transitional areas from construction zones to sections of older highways should be carefully designed and located so that the driver can adjust to the reduced standards or changed conditions. It should be recognized that these transitional areas may remain in place for a period of time until the adjacent section of roadway is improved. The following factors should be considered when designing, constructing, and operating these transitional areas:

- Provide adequate sight distance and geometrics consistent with the roadway having the higher design speed.

- If channelizing devices other than portable barriers are used, they should be lightweight or yielding.

- Sign supports should be yielding or breakaway. Pavement markings should be used to provide a well defined path.

- Transitional areas should be kept clear of unnecessary hazards.

9. Pavement Drop-offs

Highway agencies have varying opinions as to which depth of pavement drop-off needs some type of treatment. They also have varying opinions as to the type of treatment that should be used. A research project is underway that may provide guidance as to where and what type of devices to use for drop-offs of different depths with varying roadway conditions.

Drop-offs should be kept to a minimum in frequency, duration, and depth. When they are inevitable, good judgment should be used to determine the treatment that will be employed. The following items should be considered when developing a TCP for a project that will have pavement drop-off conditions:

- Where possible, the contract should limit the amount of difference in elevation between adjacent lanes.

- The time that a difference in elevation will be allowed should be limited.

- Signs can be used to advise motorists of the drop-off condition.

- A fillet or wedge of gravel or paving material can be placed as shown in Figure 7 (page 56).

- Where excessive drop-offs are necessary it may be possible to close the adjacent lane with appropriate channelizing devices. If the adjacent lane cannot be closed, it may be necessary to install longitudinal roadside barriers such as guardrail or portable concrete barrier.